8-20-2017

Characterization of biochar pore structure with X-ray tomography

Jari Hyväluoma
Natural Resources Institute Finland (Luke), Finland

Jaakko Heikkinen
Natural Resources Institute Finland (Luke), Finland

Sampo Kulju
Natural Resources Institute Finland (Luke), Finland

Markus Hannula
Tampere University of Technology, Finland

Hanne Wikberg
VTT Technical Research Centre of Finland Ltd., Finland

See next page for additional authors

Authors
Jari Hyväluoma, Jaakko Heikkinen, Sampo Kulju, Markus Hannula, Hanne Wikberg, Anssi Källi, and Kimmo Rasa

Characterization of biochar pore structure with x-ray tomography

J. Hyväluoma, J. Heikkinen, S. Kulju, M. Hannula, K. Arstila, H. Wikberg, A. Källi, K. Rasa

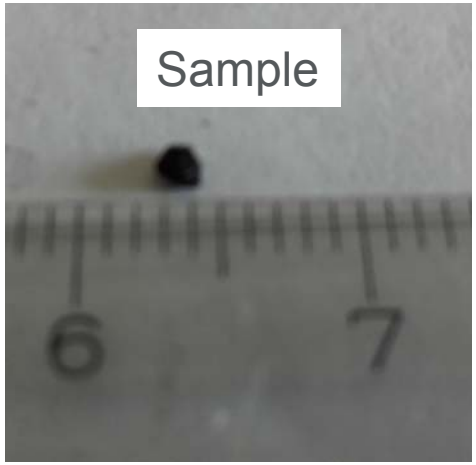
Biochar: Production, Characterization and Applications

August 20-25, 2017

Alba, Italy

Luke
NATURAL RESOURCES INSTITUTE FINLAND

X-ray tomography & image analysis



Imaging

Raw data

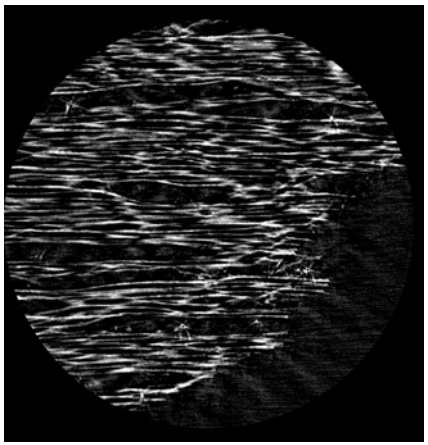
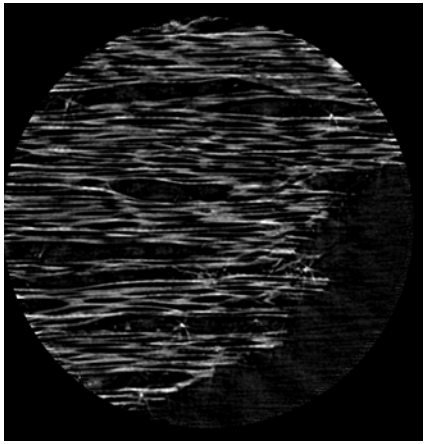


Image processing and visualization



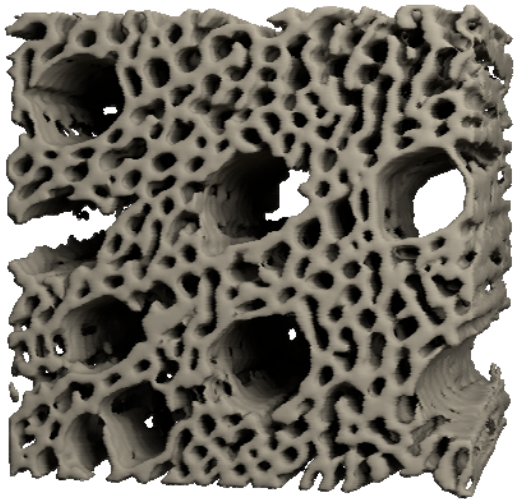
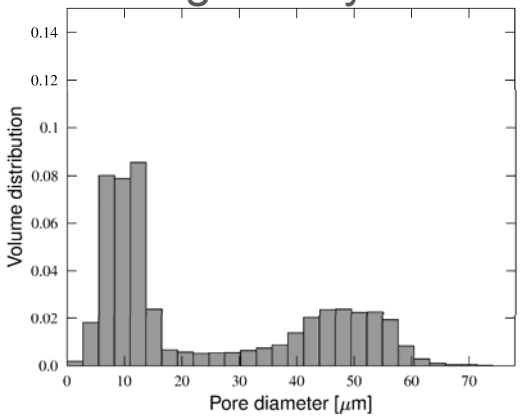


Image analysis

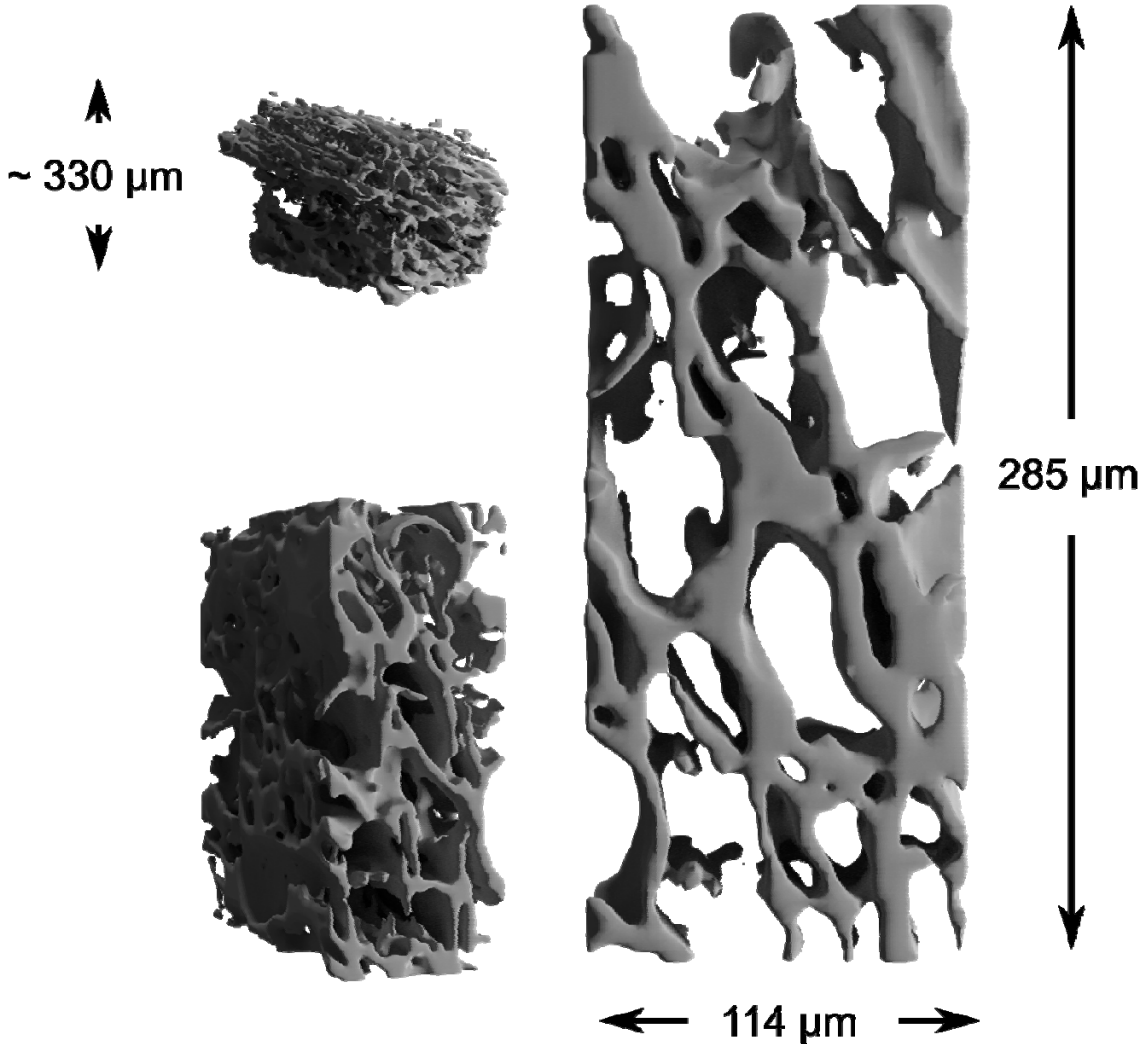


Luke
NATURAL RESOURCES INSTITUTE FINLAND

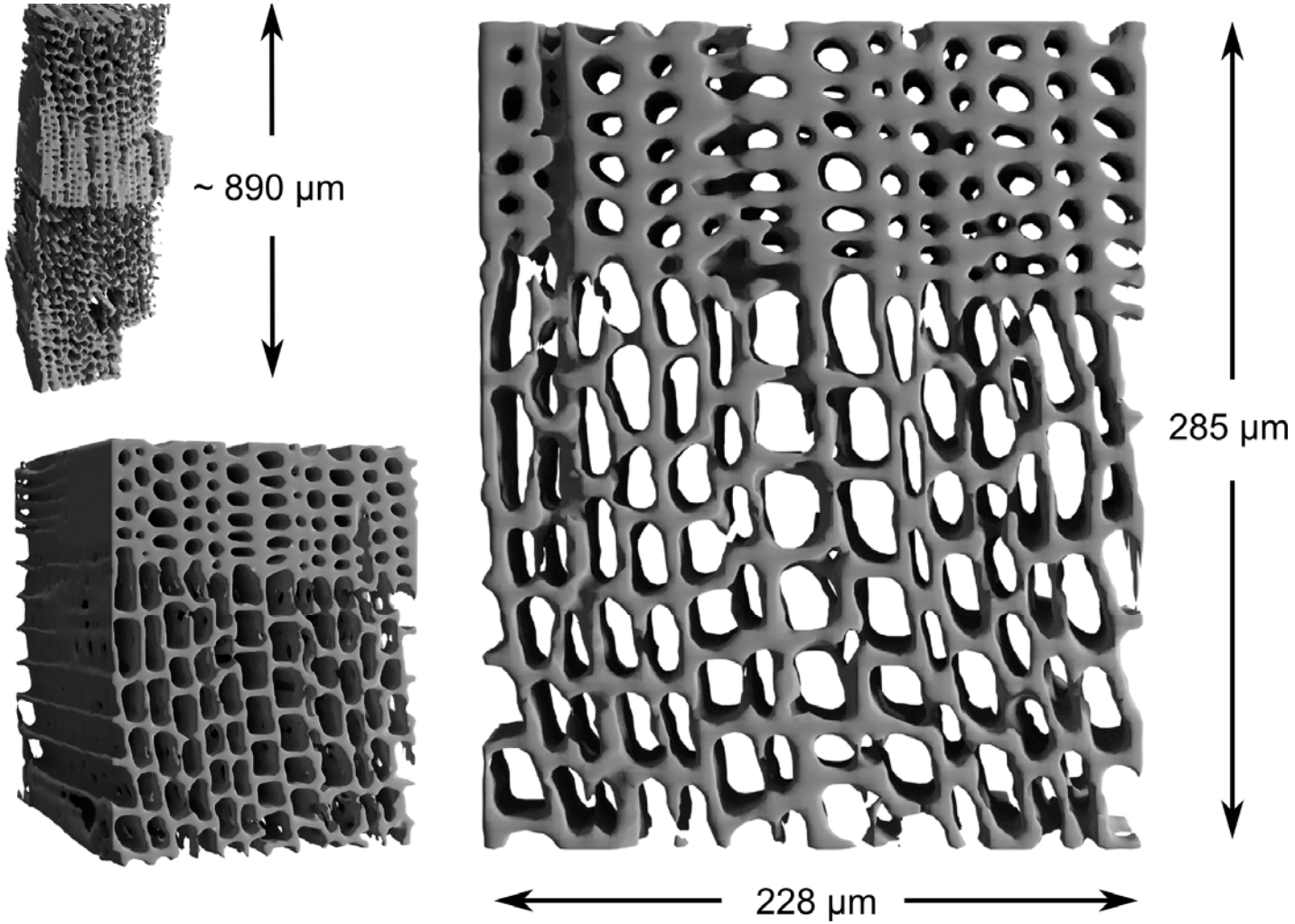
Motivation: soil moisture characteristics of biochar amended soils

- Relevant scales:
  - Field capacity (FC): matric potential -10 kPa, equivalent pore diameter **30 µm**
  - Permanent wilting point (PWP): matric potential -1500 kPa, equivalent pore diameter **0.2 µm**
  - Plant available water (PAW): volumetric water contents between FC and PWP, held in pores with diameter between **0.2** and **30 µm**
  - Easily plant available water (EPAW): volumetric water contents between -10 kPa and -316 kPa, held in pores between **1** and **30 µm**
- There is a need to characterize pores in micron-scale range!
- In this work, imaging resolution was **1.14 µm**

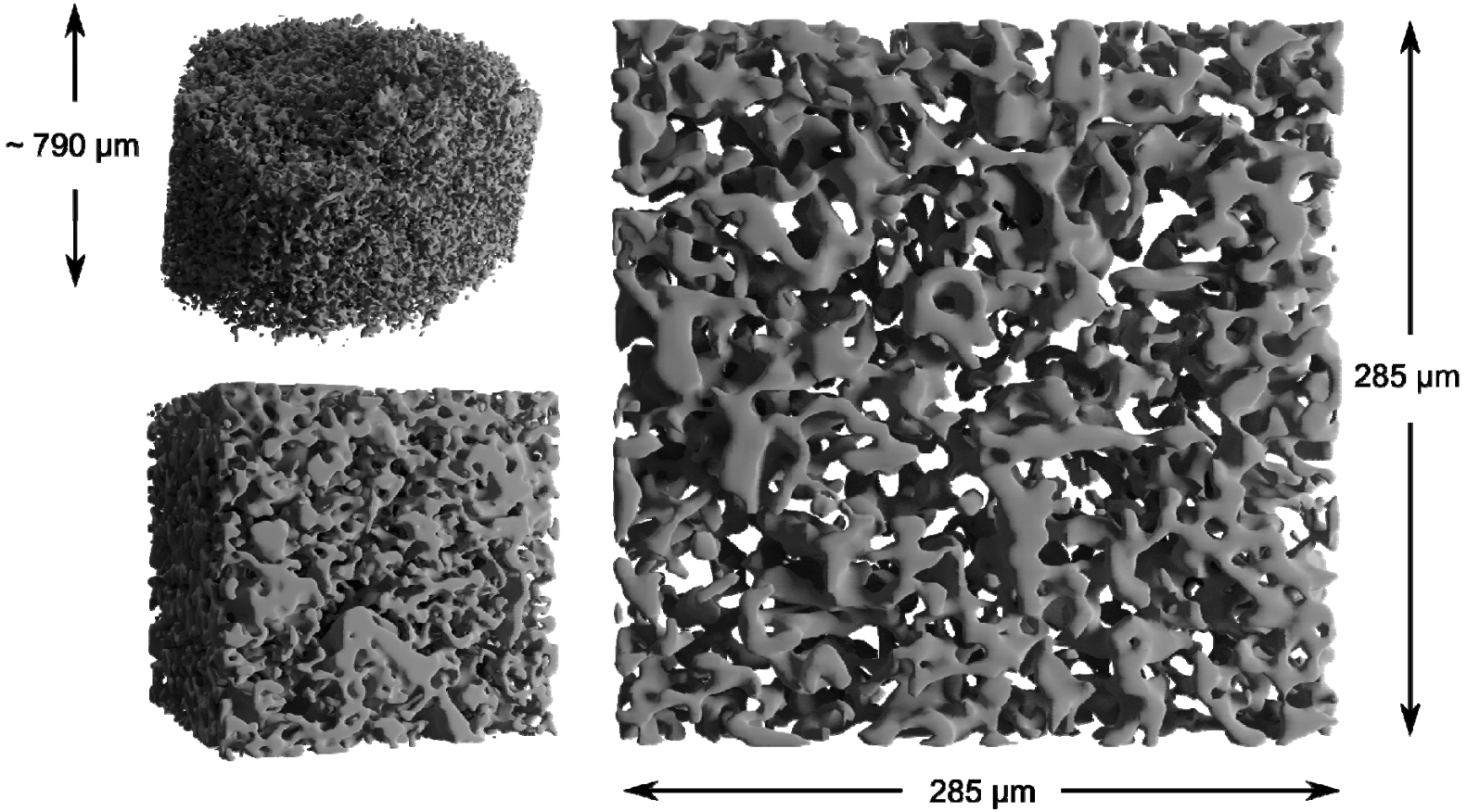
Example 1: Scots pine bark



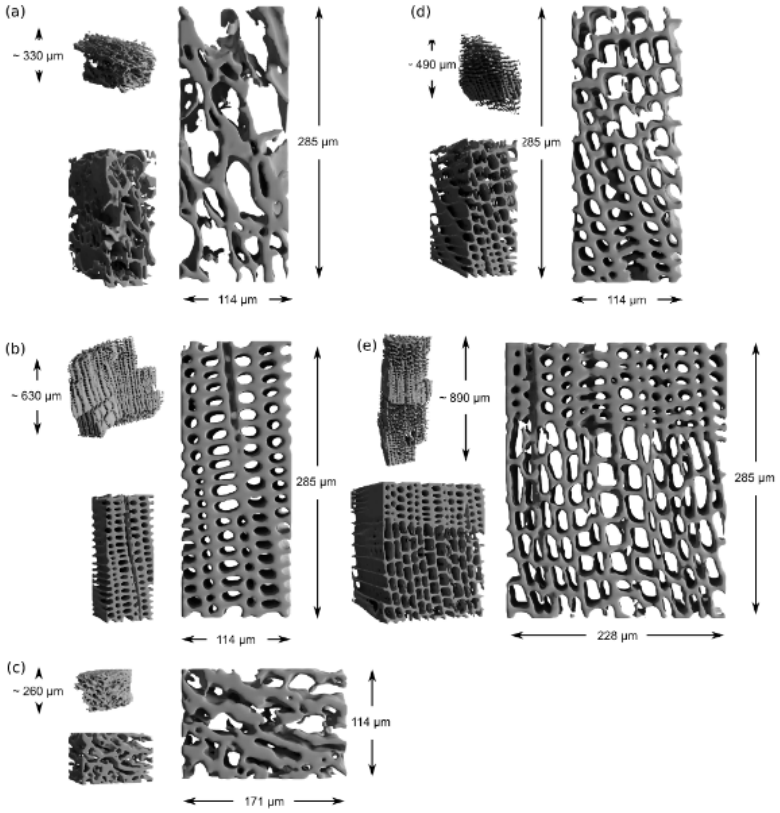
Example 2: ”Scots pine bark”

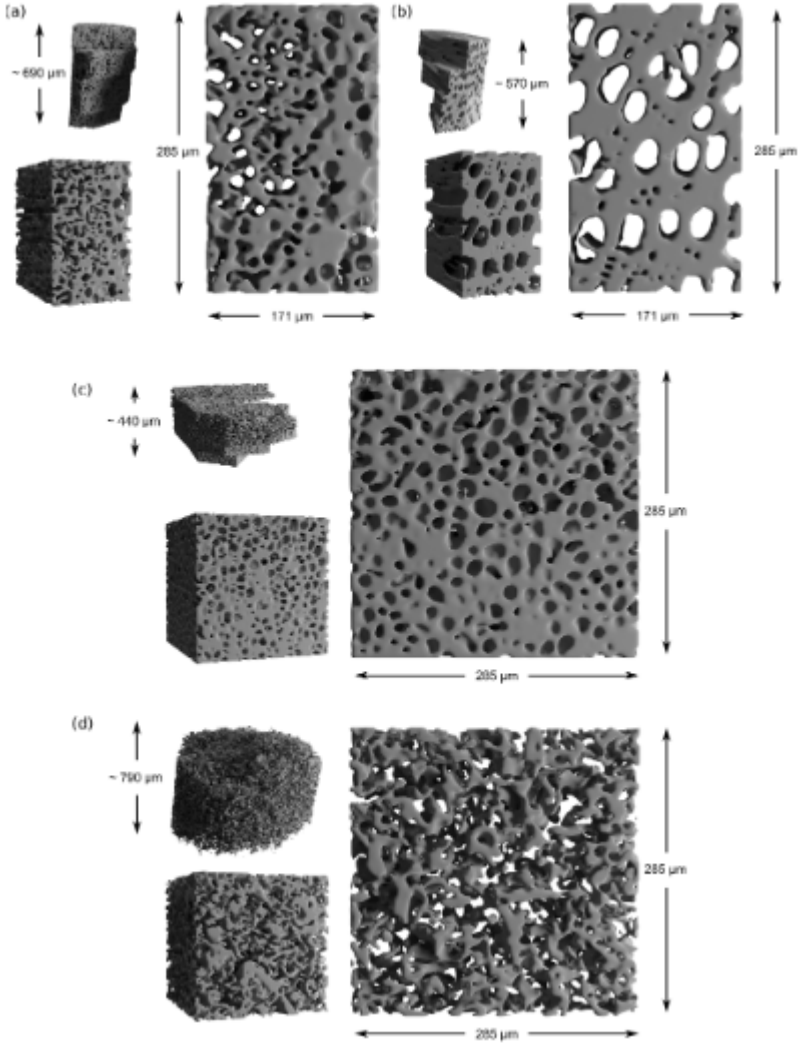


Example 3: Coffee cake



Additional examples





Hyväluoma, Kulju, Hannula, Wikberg, Källi & Rasa, *Quantitative characterization of pore structure of several biochars with 3D imaging*, Environmental Science and Pollution Research, in press (2017).

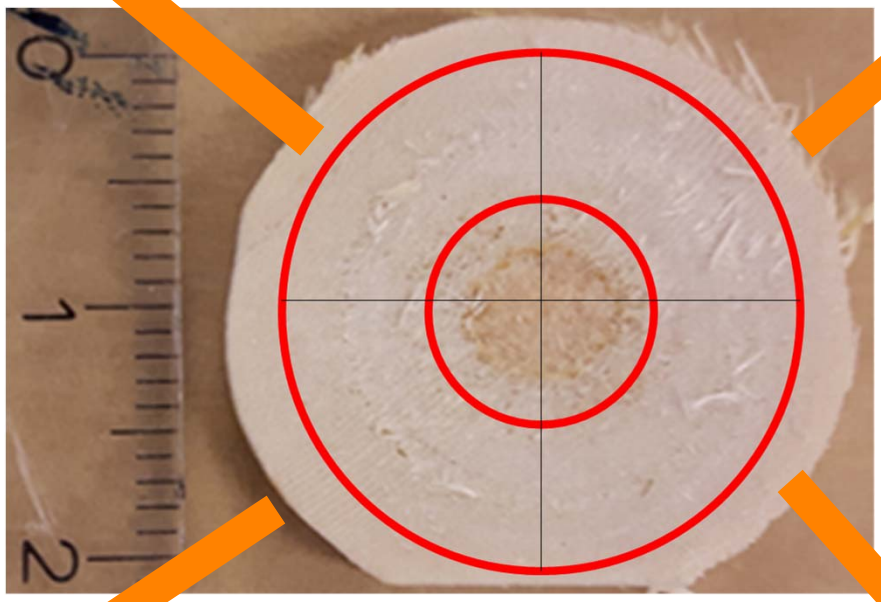
Luke
NATURAL RESOURCES INSTITUTE FINLAND

Some results for willow biochar

Effect of pyrolysis temperature on hydrologically relevant porosity

Control: dried T=60 ºC

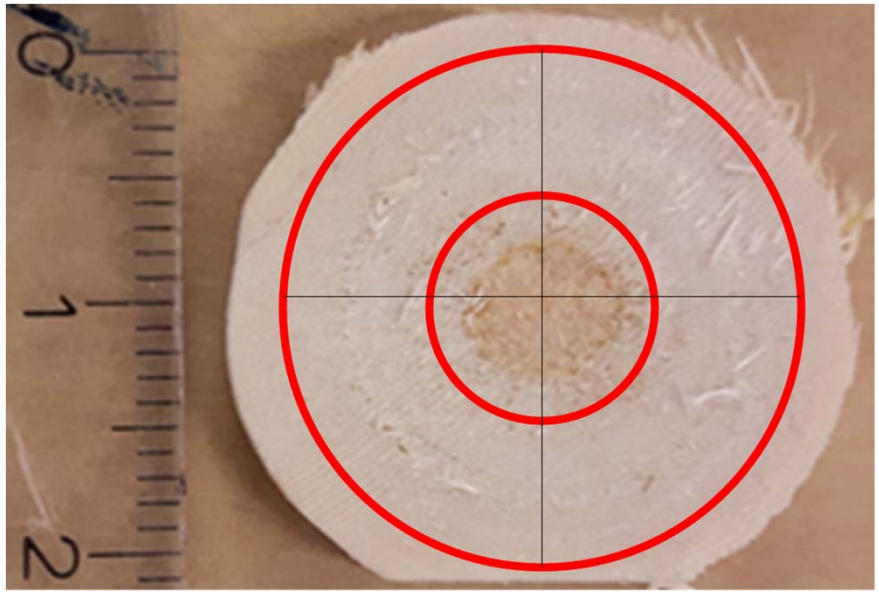
Pyrolysed T = 489 ºC

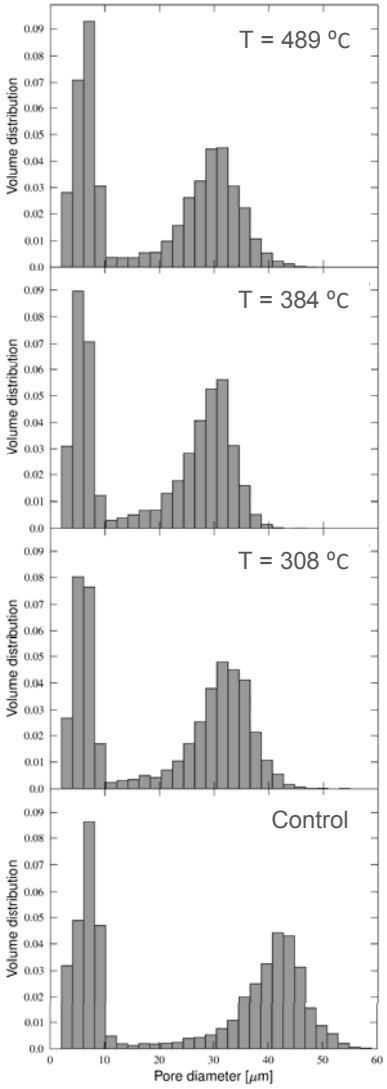


Pyrolysed T = 308 ºC

Pyrolysed T = 384 ºC

Effect of pyrolysis temperature on hydrologically relevant porosity





Temperature does not affect micron-scale porosity (but may affect surface chemistry!)

Effects of biochar on soil moisture characteristics: materials

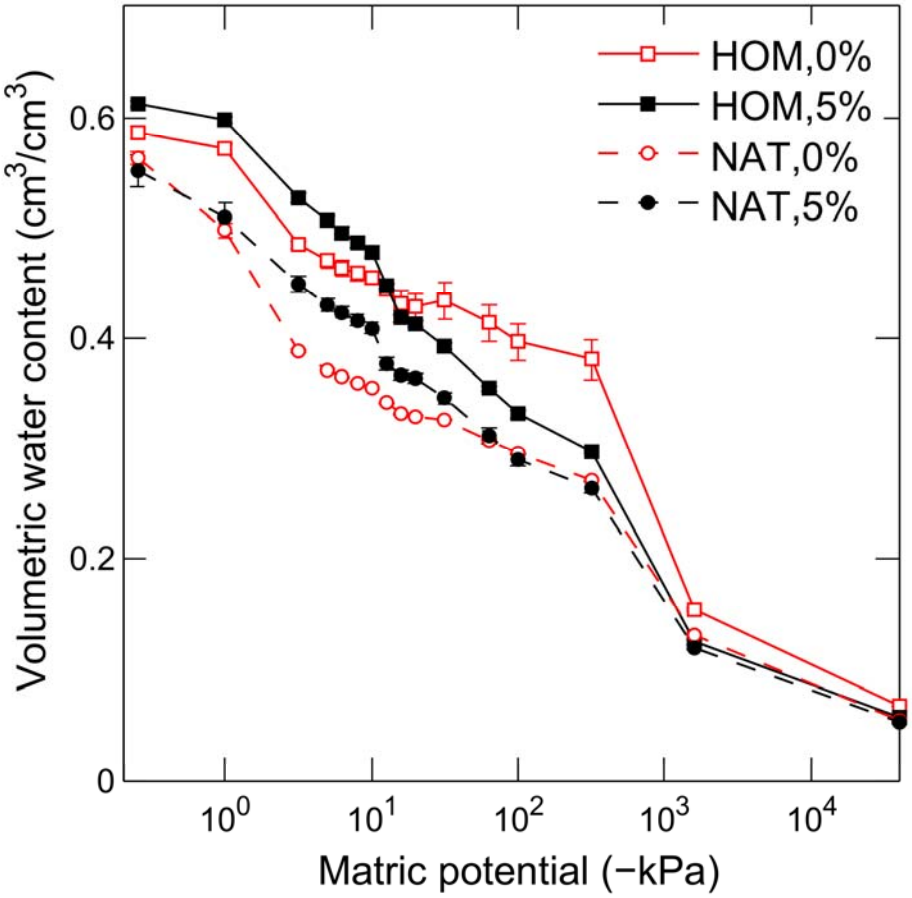
- Comparison of image analysis results and soil moisture characteristic

- Heavy clay soil (65% clay), two soil types:
  - Natural aggregate structure (air dried soil sieved through a 6 mm mesh)
  - Homogenized soil (ground with a roller mill and sieved through a 2 mm mesh in order to destroy aggregate structure)

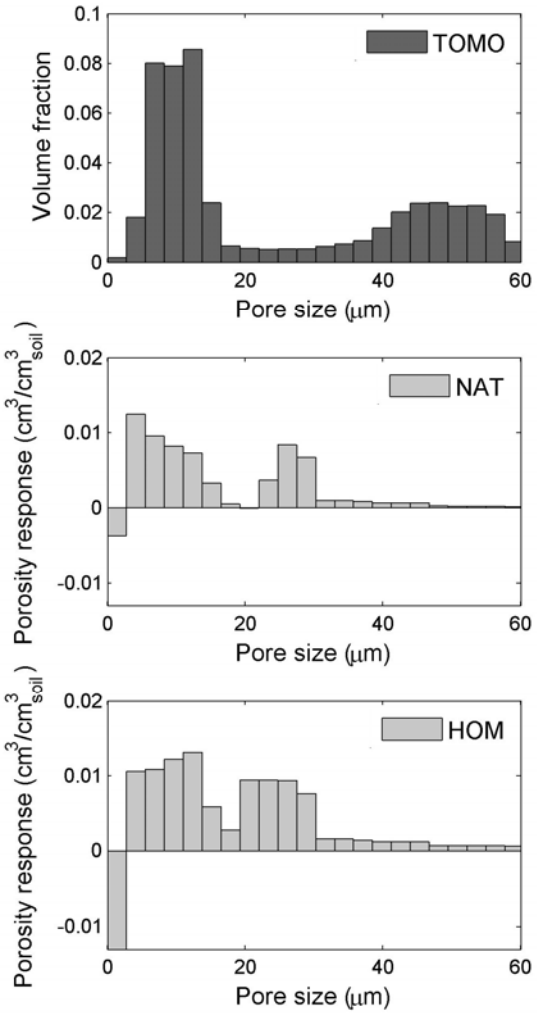
- Biochar treated soil (5% dry matter weight) vs. control without biochar

Effects of biochar on soil moisture characteristics

SMC curves:



Effects of biochar on soil moisture characteristics: comparison with image analysis



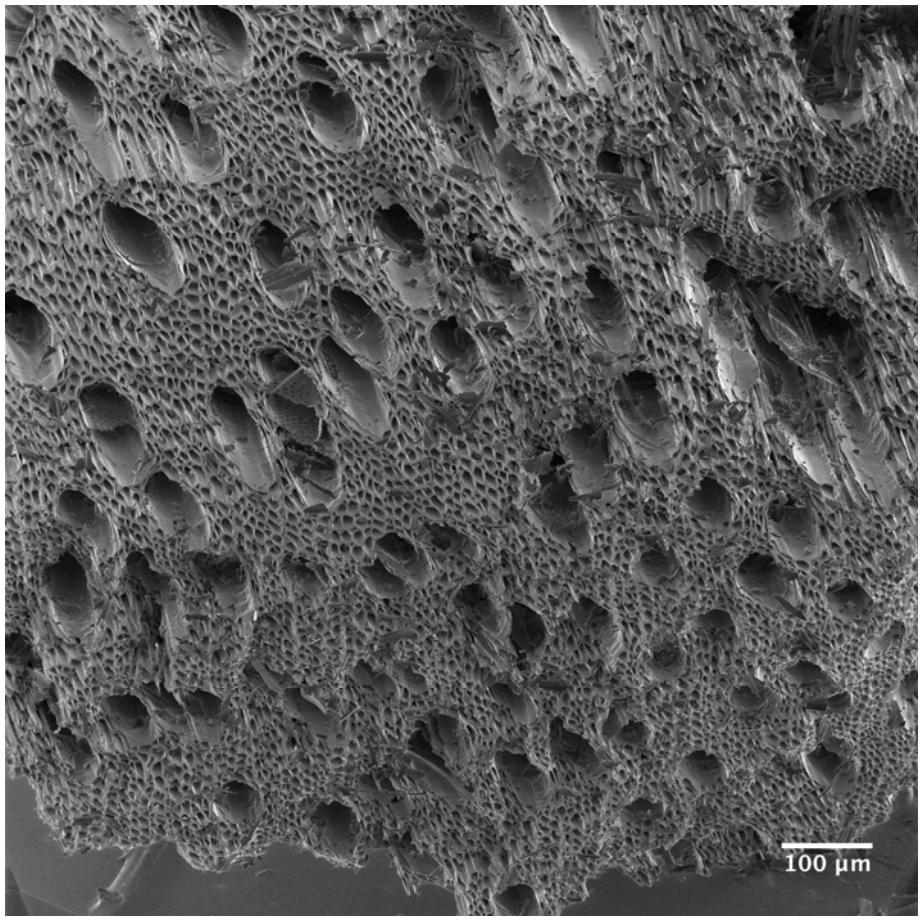
Pore size distribution determined with image analysis

Difference curves: difference in soil water contents (=pore volume) between biochar-treated and control samples

Luke
NATURAL RESOURCES INSTITUTE FINLAND

What about porosity smaller than imaging resolution? - Helium ion microscopy

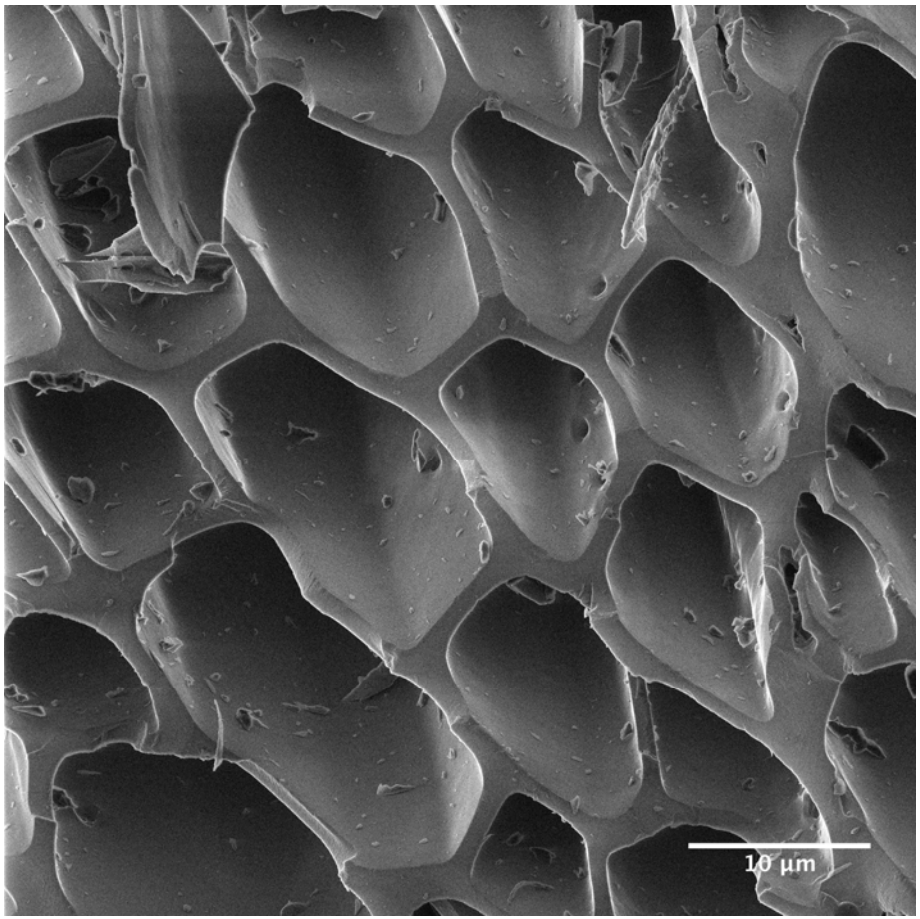
1 mm × 1 mm:



Luke
NATURAL RESOURCES INSTITUTE FINLAND

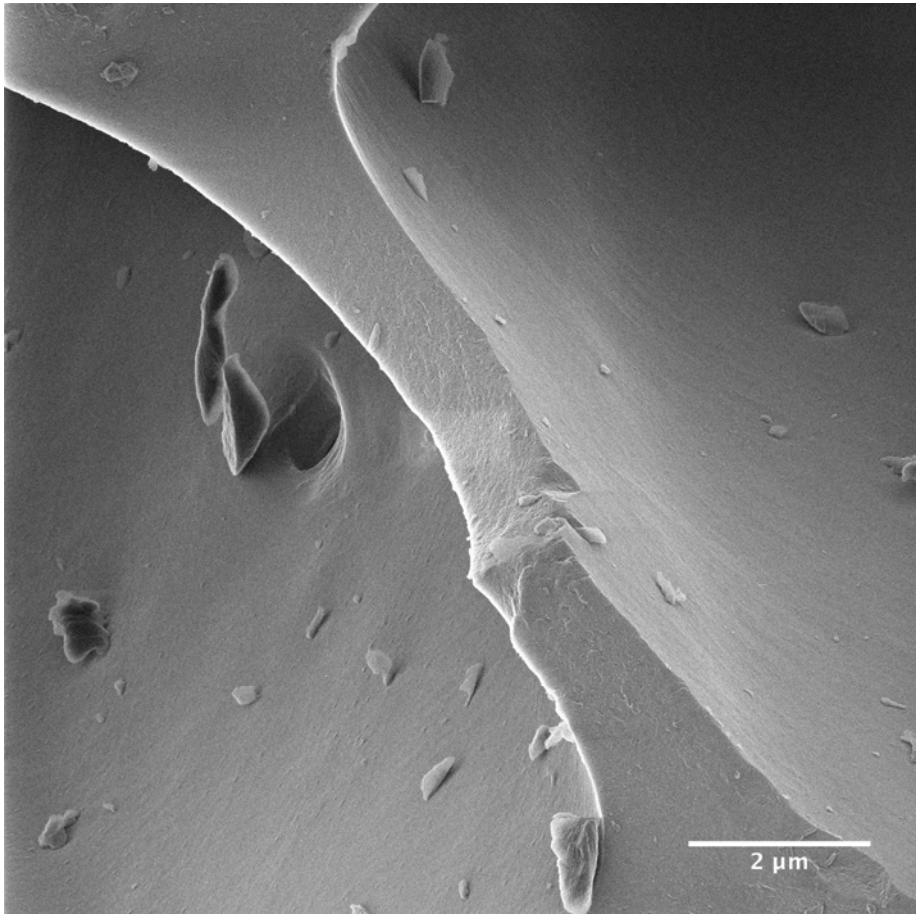
What about porosity smaller than imaging resolution? - Helium ion microscopy

50 µm × 50 µm:



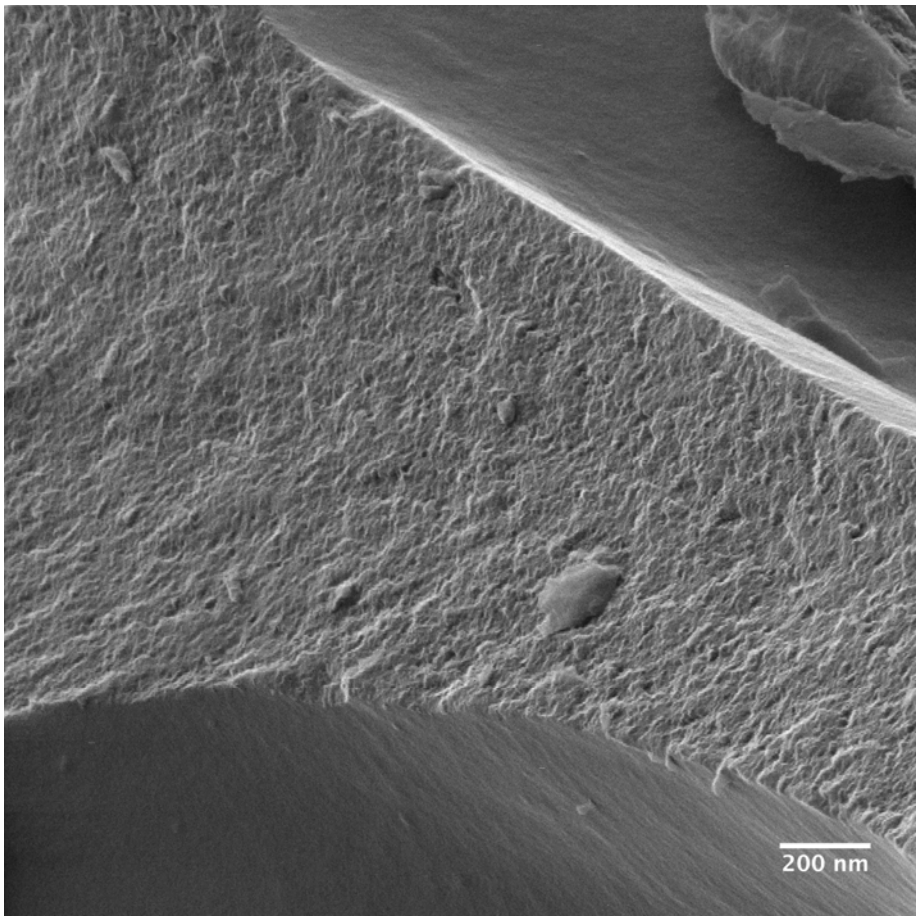
What about porosity smaller than imaging resolution? - Helium ion microscopy

10 µm × 10 µm:



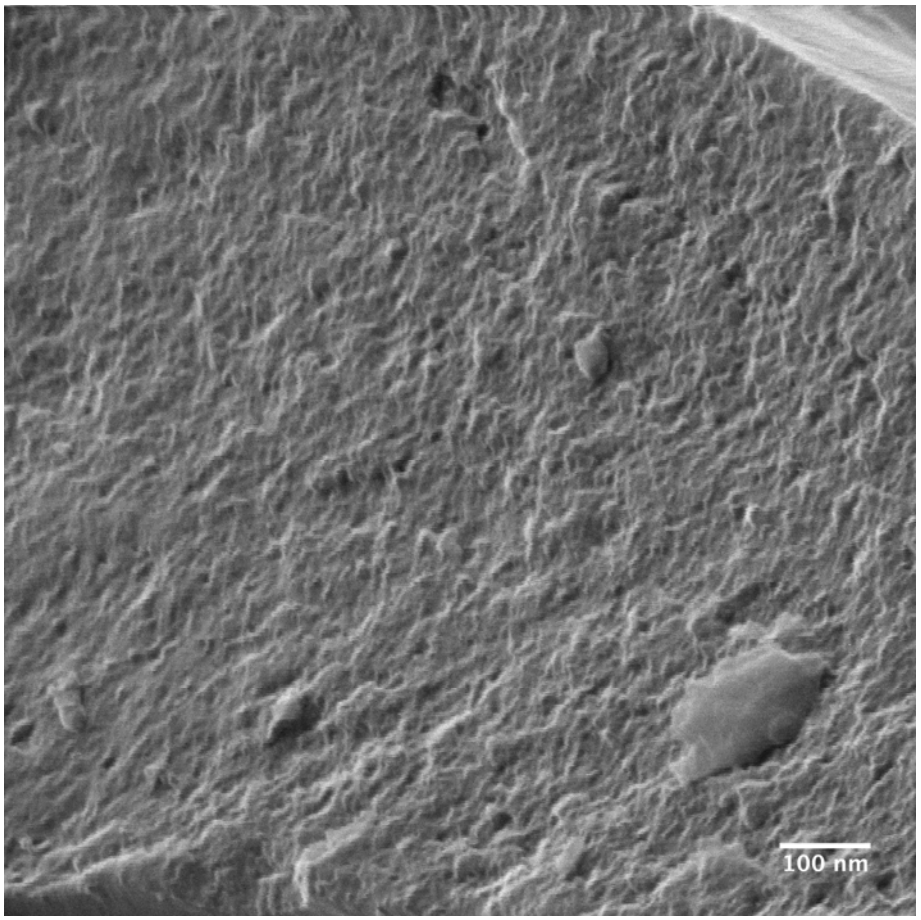
What about porosity smaller than imaging resolution? - Helium ion microscopy

2 µm × 2 µm:



What about porosity smaller than imaging resolution? - Helium ion microscopy

1 µm × 1 µm:



Conclusions

- 3D imaging provides direct information of biochar porosity on hydrologically relevant length scales
- Imaging helps to improve predictability of biochar effects on soil moisture characteristics
- Micron-scale porosity has direct effect on soil moisture characteristics
- Pyrolysis temperature had not significant effect on micron-scale porosity, plant cell structure determines the pore-size distribution of biochar

Acknowledgements

Work conducted as a part of European Mobile Flip project, which has received funding from the EU Horizon 2020 research and innovation programme.

